

A Half-Wave Hula-Hoop Antenna for GSM Mobile Applications

Here is a low-profile antenna option for applications requiring low visibility, durability and a uniform radiation pattern

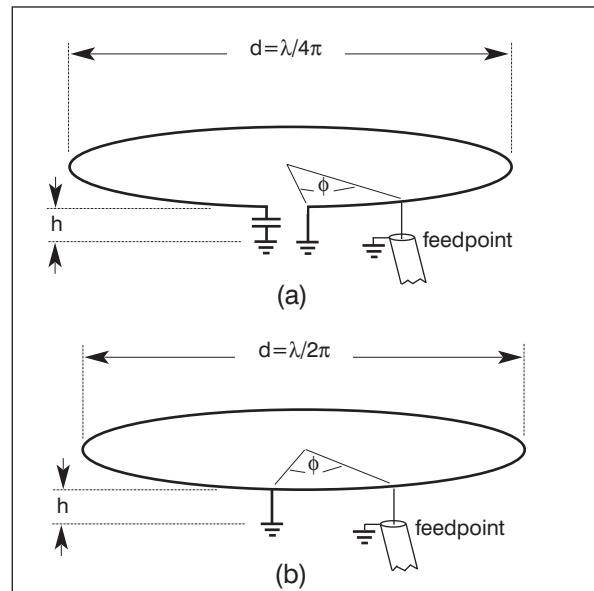
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This article describes an investigation into the input impedance bandwidth and radiation characteristics of a half-wave hula-hoop antenna. The antenna is designed to work in the GSM frequency band of 860-960 MHz. Theoretical and experimental results are presented, showing the antenna's capability of producing nearly isotropic radiation patterns. The basic antenna structure is metallic and does not involve any dielectric materials, enabling an inexpensive and easy-to-construct low-profile antenna design.

Low-profile antennas have been used in specialized and covert applications in Professional Mobile Radio (PMR) for many years. They were initially designed to satisfy the need for almost indestructible antennas. The aesthetic appeal of low-profile designs and their durability are their main marketing advantages. On the other hand, GSM is increasingly employed in mobile location services, especially tracking and remote services. Tracking services, for example, are used to locate and monitor cargoes, and remote services are used for long-distance control of vehicle functions, etc. most of these applications require robust low-profile antennas with an omni-directional radiation pattern. This article introduces one such design, which is inexpensive to produce and has good RF performance.

Structure of the antenna

The hula-hoop antenna, also known as a directional-discontinuity ring-radiator (DDRR) gained a lot of attention in the early 1960s [1-3]. The original version consists of a quarter-wavelength long piece of wire bent into a circular shape over a conductive ground plane, as illustrated in Figure 1a. The position of the loop is



▲ Figure 1. Hula-hoop antennas: (a) the quarter-wave loop, and (b) the half-wave loop.

parallel and close to the ground plane. The loop is driven at one of its ends and open at the other. The antenna resonant frequency can be lowered by capacitive tuning at the open end. The basic idea of this design is to replace a quarter-wave monopole antenna with a shorter but wider radiating structure with similar electrical characteristics. The quarter-wave DDRR has, however, been proven to have the input impedance bandwidth of only one to two percent [4].

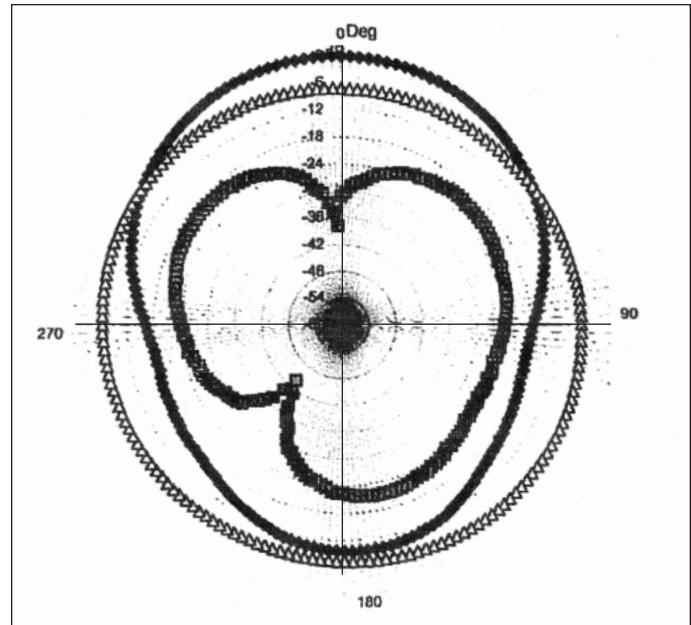
In order to increase the input impedance bandwidth, a closed half-wave loop structure has been proposed (Figure 1b) [4]. A half-wavelength long piece of wire is bent into a circle and short-circuited to a ground plane at one point.

Loop Diameter (mm)	Loop Height (mm)	Resonant Frequency (MHz)	Bandwidth (MHz)
50	30	1050	90
50	35	975	85
50	40	910	70
50	45	855	60
60	25	1040	120
60	30	960	105
60	35	900	80
60	40	840	70
60	45	795	65
70	25	940	50
70	30	880	65
70	35	825	70
70	40	775	60
70	45	735	60
80	25	870	45
80	30	760	50
80	35	760	55
80	40	720	60
80	45	685	60

▲ **Table 1.** Antenna resonant frequency and bandwidth as a function of loop diameter and height.

The antenna is fed by a coaxial cable at another point. The position of the feed point is usually 100° to 140° away from the short-circuit point. By changing the original quarter-wave long, open hula-hoop design into a half-wave long closed-loop design, a noticeable improvement in the input bandwidth can be achieved.

The antenna was modeled using WIPL [5]. Initial numerical results showed that the antenna impedance



▲ **Figure 3.** Radiation pattern (azimuth) at 925 MHz. Triangles are vertical polarization, squares are horizontal polarization and diamonds are the reference horn antenna.

bandwidth was strongly dependent on the size of the ground plane. For practical reasons, the ground plane was chosen to be circular with a diameter of 240 mm.

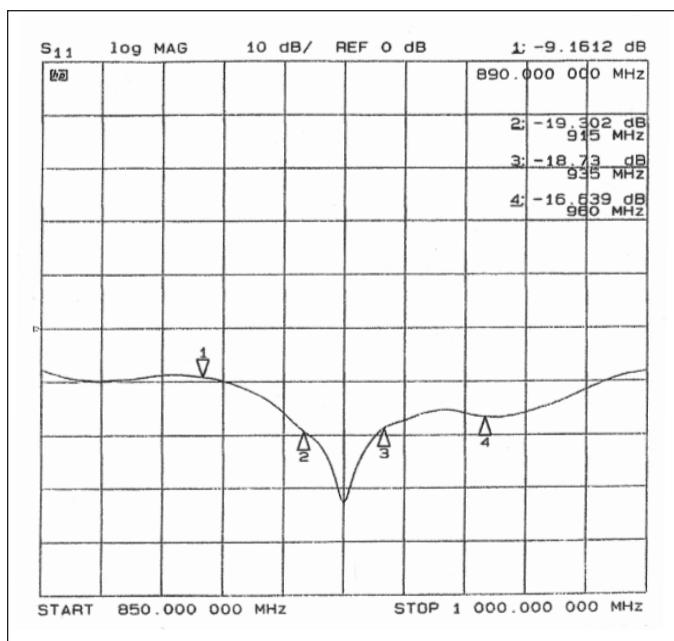
The loop diameter and its height above the ground plane were then changed and the antenna resonant frequency and input impedance bandwidth were calculated. The numerical results are shown in Table 1. As expected, the resonant frequency decreases with an increase of both loop diameter and its height above the ground plane.

In order to cover the whole of the GSM band (890–960 MHz), the loop diameter was chosen to be 60 mm and its height was chosen to be somewhere between 30 and 35 mm. The final value for the height was determined experimentally.

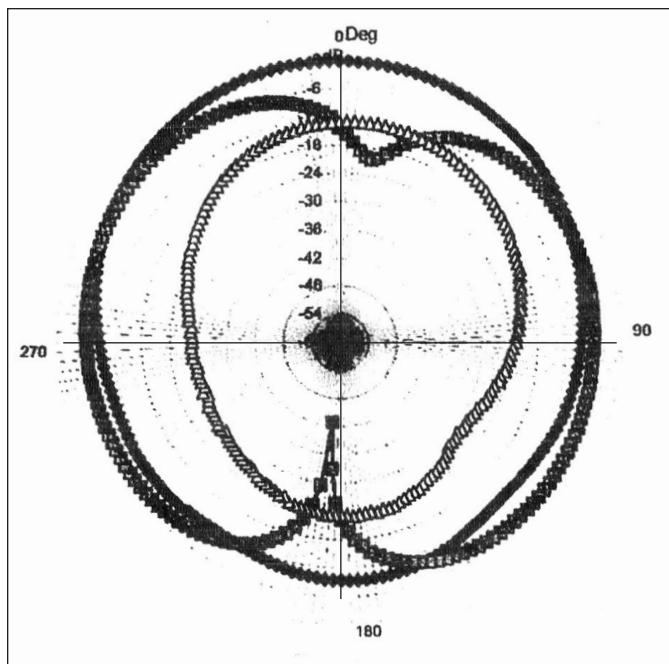
Antenna electrical characteristics

A prototype antenna was built and tested. the antenna's input reflection coefficient as a function of frequency is shown in Figure 2. The bandwidth (-10 dB) is about 90 MHz.

The antenna radiation patterns in the azimuth and elevation planes are shown in Figures 3 and 4, respectively. The antenna has an almost omni-directional radiation pattern. The peak gain is 0.2 dBi in the azimuth plane and 2.0 dBi in the elevation plane. The gain was measured using a double-ridged horn as a reference antenna. The horn peak gain was 6.3 dBi. The fair amount of cross-polarization in the elevation plane is considered to be beneficial for applications involving multipath fading.



▲ **Figure 2.** Measured antenna input reflection coefficient vs. frequency.



▲ **Figure 4. Radiation pattern (elevation) at 925 MHz.** Triangles are vertical polarization, squares are horizontal polarization and diamonds are the reference horn antenna.

Conclusion

A half-wave hula-hoop antenna has been described. The antenna operation was analyzed both theoretically and experimentally. It has been shown that the antenna has an almost omni-directional radiation pattern. The antenna also has a low profile and is inexpensive and easy to manufacture. The design presented here is suitable for GSM applications. ■

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